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ELECTRON DENSITY DISTRIBUTION IN THE NEAR WAKE<sup>+</sup>

by

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ABSTRACT

Recently, attention has been focused on theoretical descriptions and experimental measurements of the effects of physical and chemical processes in wakes of high velocity bodies. The interest in this aspect of wakes, apart from purely fluid-mechanical phenomena, is significantly related to the thermal ionization effects associated with reentry, and the relevant problems of observation and communication. In particular, the electron density distribution in the wake of typical reentry vehicles has received much attention. To obtain the latter, ground-based as well as actual inflight measurements have been made. To date most of the experimental studies involving ionized wakes have been performed in ballistic ranges using predominantly optical, microwave, and probe methods to obtain the desired plasma parameters. Due to the physical limitations of such

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facilities, and their mode of operation, the data, temporal or spacial, are usually limited to average cross-sectional values. Accordingly, for example, the scientists at the Lincoln Laboratories present their data in terms of electron density per unit length, and those of G.M.D.R. Laboratories present their data in terms of electron density per unit area. The experimental electron density data thus far available relate predominantly to the far wake. Experimental data on the electron density distribution in the near wake or recirculation region of reentry-type bodies is very scarce.

In the present work an attempt is made to obtain detailed point-wise electron density distributions in the near wake, utilizing a shock-tunnel for that purpose. The test flow is slightly ionized and chemically frozen. Typical reentry type configurations, among which are a hemisphere cylinder and a  $10^\circ$  half-angle cone model, were chosen for the investigation. To achieve spacial resolution, the sizes of the models were chosen large enough to accommodate a number of sensors while minimizing their mutual interference.

As the diagnostic instruments, Langmuir-type probes arranged in the form of a rake were selected. The rake mounted behind the suspended model in the center of the tunnel test section, could be adjusted on its axis relative to the model base. Due to physical limitations of the tunnel, this axial motion of the rake was limited to about 6 feet. Figure 1 presents a photographic view of the

experimental arrangement. In this figure, the 12.75" base diameter hemisphere cylinder model, suspended in the test section with the rake of electrostatic probes mounted behind it is shown. The test section flow conditions were chosen to satisfy the requirements imposed on cylindrical probe operation by the Laframboise collisionless theory. Flow field considerations in the near wake, and particularly in the recirculation region, resulted in the electrostatic probe rake configuration as seen in Figure 1. With the above test configuration and test section flow conditions of Mach number 18.2 density of  $1.10^{-5}$  atmospheric density and free stream electron density of  $8.10^8$  el/cm<sup>3</sup>, a series of tests were performed with the rake at a number of axial positions for each of the several models. Figure 2 presents a normalized plot of some of the electron density distribution profiles in the near wake for the 12.75" base diameter hemisphere cylinder model. The electron density was normalized here with respect to a probe which was located at the extreme end of the rake, outside of the viscous wake region but in the inviscid region behind the bow shock. As a parameter in this figure, the normalized axial distance  $x/d$  from the base of the model is used. The same type of a plot was obtained for the smaller 4" base diameter hemisphere cylinder model. Figure 3 presents a comparative normalized profile of the electron density in the recirculation region with the

ake of probes .25D behind the models, as a function of the normalized distance from the center line with the model diameter as the normalizing factor. The electron density for the 4" diameter hemisphere cylinder model was normalized with respect to the free stream electron density and matched to the normalized density of the 12.75" model at a specific  $y/d$  axial location. Finally, in Figure 4 the normalized electron density distribution for the  $10^\circ$  half-angle cone model is shown. An overshoot of the electron density at the outer edges of the wake, its spreading away from the axis of the wake and its simultaneous gradual decrease in amplitude with the increase of the distance from the base of the model should be noted. The above experimental curves, although presenting only a small fraction of the data obtained in this investigation clearly demonstrates the great potentialities available in using the shock tunnel and electrostatic probes for detailed near-wake experimental investigations.

It must be pointed out here that although absolute values of the electron density were obtained, there are some difficulties in the recirculation region which had to be dealt with. These and other aspects of this investigation, including fluid mechanical considerations, will be discussed in more detail in the prepared paper.

To summarize, it is shown that:

1. The shock tunnel can - within limits - be used to great advantage to obtain detailed information on the electron density profiles in the near wake and in the recirculation region.
2. The relative electron density in the recirculation region for both blunt and slender bodies may vary over a range of 3 orders of magnitude.

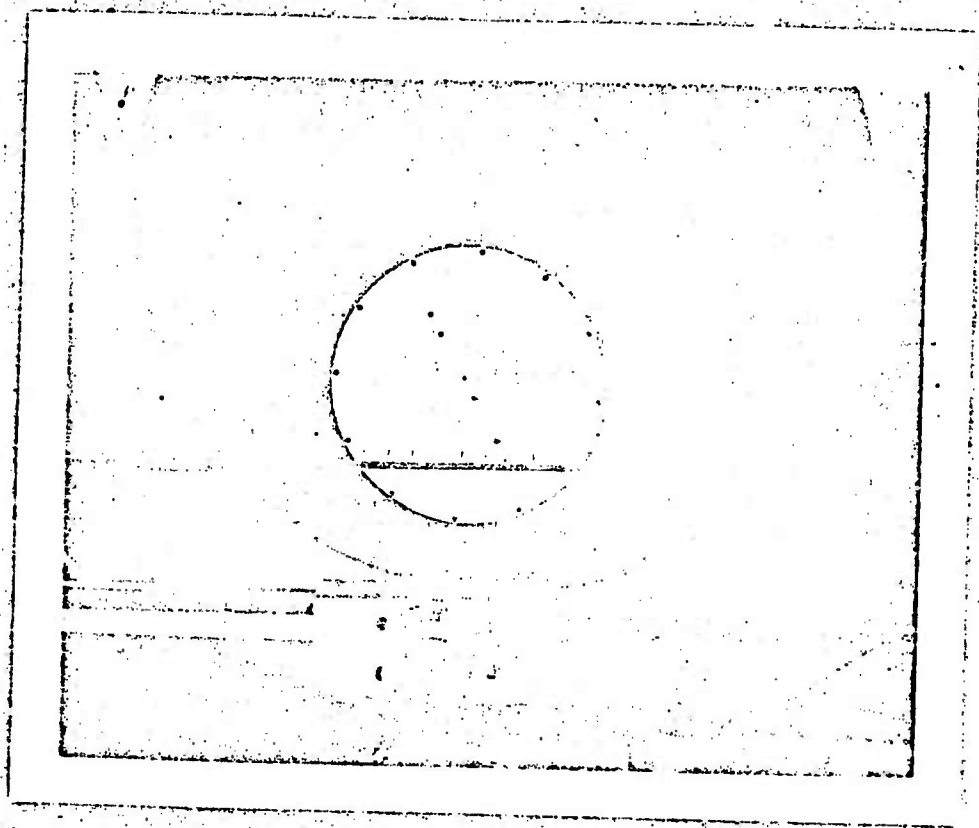


FIG. 1 PHOTOGRAPHIC VIEW OF THE EXPERIMENTAL SET UP

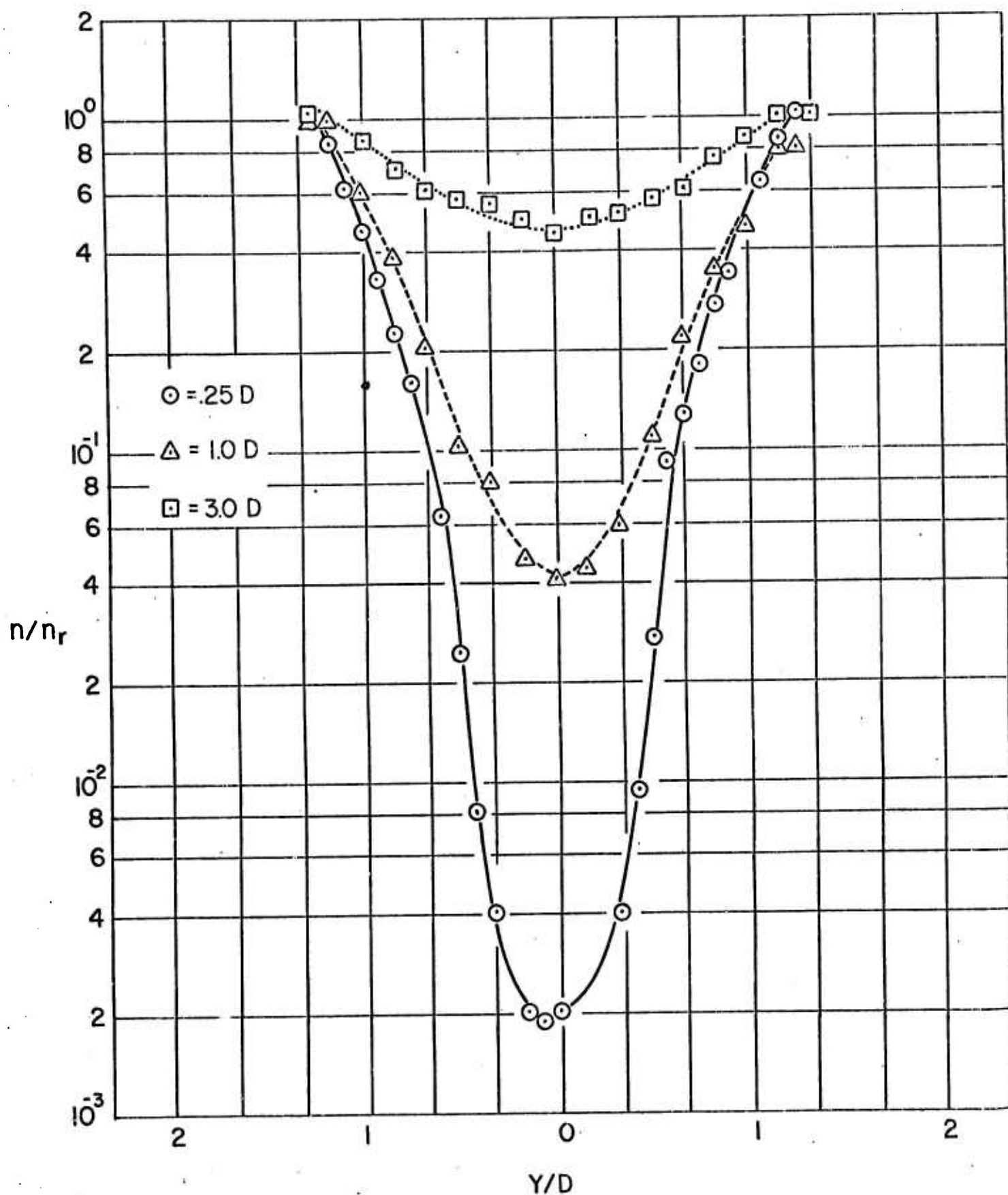


FIG. 2 NORMALIZED ELECTRON DENSITY IN THE WAKE OF A HEMISPHERE CYLINDER MODEL



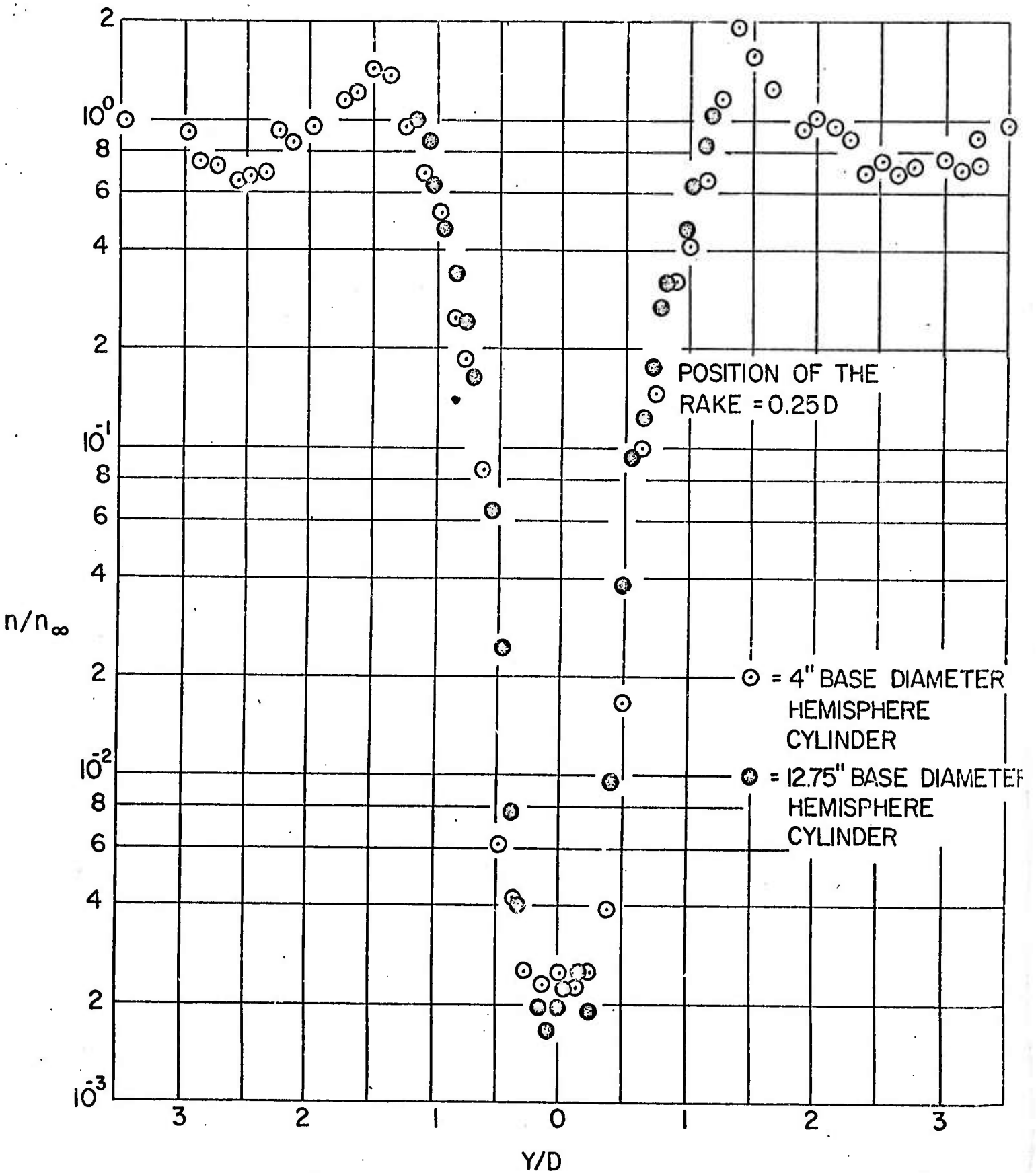


FIG. 3 NORMALIZED ELECTRON DENSITY IN THE WAKE  
VS. NORMALIZED DIAMETER

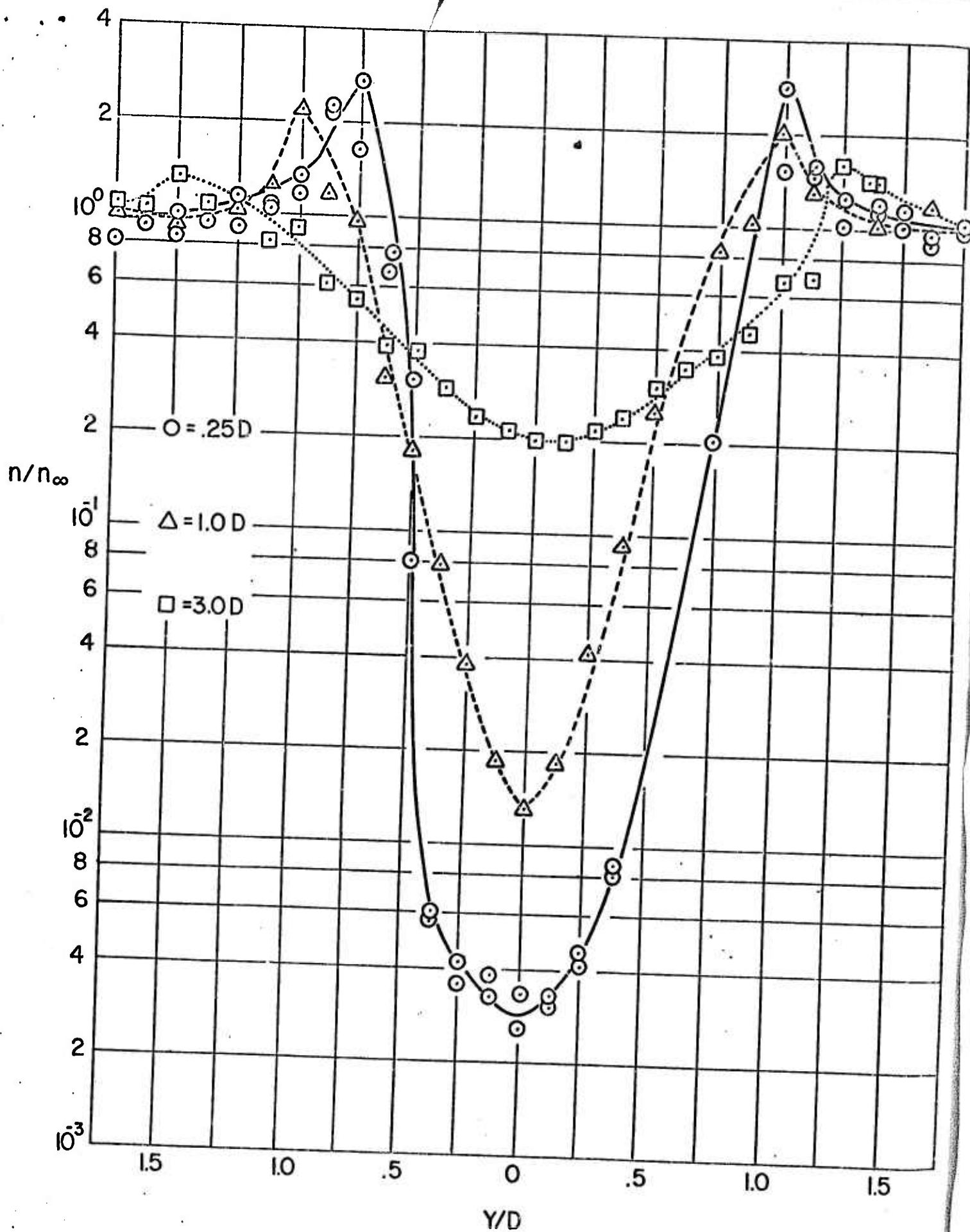


FIG. 4 NORMALIZED ELECTRON DENSITY IN THE WAKE OF  $10^\circ$  HALF ANGLE CONE